Paper Number 2004-01-028

REPORTING AIRLINE SAFETY PERFORMANCE AND FINDING THE SENSITIVITY OF AIRLINE SAFETY FACTORS

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This study aimed to review airline safety performance and to discover the performance sensitivity of 17 selected safety factors utilized in the measuring mechanism, namely the Airline Safety Report (ASR). The initial study of ASR was an application of the National Airline Quality Rating (AQR) and simultaneously embraced the usage of Analytical Hierarchy Process (AHP) software and Delphi technique. Due to the financial constraint eroding airline's capacity in closing all identified safety deficits, prioritizing enhancement tasks for airlines is essential. This attempt needs a further investigation of safety factors recruited within ASR formula. Based on the calculation of performance sensitivity (Sp) of each selected safety factor, the authors prioritized factors that impacted safety performance substantially. The result showed that Accident and Management Quality were two most weighted categories in relation to safety performance. And fatality rate, average fleet age, and accident rate were three most critical selected factors affecting safety performance.

Introduction

According to the report from Gellman Research Association (GRA) (1997), Boeing Company (2000), and the Federal Aviation Administration (FAA, 2001 March), commercial air transportation is a very safe way to travel. While the whole airline enplanement had increased dramatically since 1978, the risk of fatality was reduced (Air Transport Association [ATA], n.d.). Yet this does not mean that air transportation is accident-free. Even before 9-11, several catastrophic tragedies (e.g., the crash of ValuJet flight 592, the explosion of TWA Flight 800, the fatal accident of American Airlines Flight 1420, and the mishap of Alaska Airlines Flight 261) (National Transportation Safety Board [NTSB], 2000a) have put safety performance under spotlight.

Review of Airline Safety Measurement

During the past decade, several leading media reports—the *Wall Street Journal* (Dahl & Miller, 1996, July 24; Goetz, 1998) and *USA Today* (Stroller, 2000 March 13)—have tried to rank airline safety relying on a single element such as Stroller's usage of the FAA's enforcement actions (although the FAA has been questioned about its safety inspection program) (Donnelly, 2001 March 12), Dahl and Miller's study in 1996 focusing only on accident and incident rates, and Goetz's reexamination of Dahl and Miller's former study (Goetz, 1998). Yet the research generalization about their univariate (one independent variable) evaluation seemed incredulous.

In 1991, the FAA launched its Safety Performance Analysis System; but by the late 1996, the agency had little to show for its efforts (Barchok et al., 1996). At times, the FAA inspection program seems to follow regulations to the letter; but other decisions seem to reflect high degrees of personal discretion on the part of inspectors (Lutte, 1999). Proactively, for the purpose of elevating quality of safety, a more comprehensive safety measurement mechanism for airline industry is in need ("Airline safety rating," 1997; Bowen, 1997 April). The introduction of ASR in July 2001 fulfilled such needs.

Safety Factors

To obtain the most objective measurement of airline safety, the initiative of ASR selected four safety categories recommended by GRA: (a) FAA Enforcement Actions, (b) Rates of Accident and Incident, (c) Management Quality, and (d) Financial Status. To implement the GRA's recommendation, the ASR report recruited 17 key items associated with four categories.

For the FAA Enforcement Action category, the study used the following safety factors: 1) Enforcement actions of security; 2) Enforcement actions of flight operation; 3) Enforcement actions of maintenance; and 4) Enforcement actions of hazardous material (HAZMAT). For the Rate of Accident and Incidents category, the study selected these safety factors: 1) Total fatality; 2) Fatality rate; 3) Accident rate; and 4) Incident rate. For the Management Quality category, we selected these safety factors: 1)Average fleet age; 2) Aircraft on order; 3) Code-sharing; 4) Aircraft utilization; and 5) On-time rate. For the Financial Health category, the study used the following safety factors: 1) Liquidity ratio; 2) Turnover ratio; 3) Cash flow ratio; 4) Profitability ratio. Especially important, the ASR did not discard the usage of accident or incident rates used by Dahl and Miller, Goetz, and Stroller, simply because those factors were crucial and directly helped reflect safety quality. In the former ASR report based on statistical analysis, the authors had discovered that the status of finance and quality of management are both closely relevant to airline safety.

Furthermore, in addition to Rose's financial study in 1990 indicating that profitability rates and accident rates were inversely proportional and the more safety investments contributed by airlines, the lower the accident rates would be (Rose, 1990). The ASR study reviewed several leading financial researches such as Edward I. Altman's (1968) Z-model focusing on the revenue ratio (sales over total assets, originally weighted .999 by Altman); Koundinya and Puri's (K & P) model concerning the liquidity ratio (current assets and cash flow/sales ratio) (Clark & Foster, 1997); the Cash-flow-based (CFB) ratio (cash flow to total liability) emphasized by leading financial researchers (Gardiner, 1995; Aziz, David, & Lawson, 1988 & 1989; Mossman, Bell, Swartz, & Turtle, 1998; Turpyn, 1998 July; Tae, Chang, & Lee, 1999). To summarize, the aforementioned studies emphasize current ratio (current assets over current liabilities), turnover ratio (total net income over assets), and profitability ratio (total net income over operational revenue).

Despite airline's evaluation of safety performance before signing code-share agreements with business allies ("Delta and Air France", 2002; Pasztor & Wilde, April 19, 1999; U.S. Department of Transportation [US DOT], 2000; Woellert, 1998), Lu (2003) discovered that the aviation industry intuitionally resisted support any mandatory trainings. The main reason was the concern of an unpredictable cost. Undoubtedly, such factors as professional employees, frequency of safety training, safety inspection mechanism, and technology do directly influence airline safety. Of course, this influence does not come without a strong financial support (Bowen, 1999; Donnelly, 2001; NTSB, 2000b; Oster, Strong, & Zorn, 2000).

Research Methodology

Initially, the Delphi methodology was utilized. The Delphi method is an exploratory data-collection phase that allows researchers to gain the highest validity—and ultimately, reliability—of data through repeated qualitative procedures (Kadlecek, 1997; Mitchell, 1971& 1994; Sackman, 1975; Zapka & Estabrook, 1999 October). A purposive sample was formed focusing on the in-depth exploration of selected key informants who possess direct connections to various essential and fruitful data resources (Marshall & Rossman, 1999; Maxwell, 1996; Maykut & Morehouse, 1994). One hundred and twelve (112) aviation experts were invited to participate in this research. A survey questionnaire was generated by Analytical Hierarchy Process (AHP) software and mailed to aviation experts. Pairwise comparison is the core aspect of comparing the relative importance between two or more targeted safety factors systematically selected from a pool of safety factors (Expert Choice, 1994; Saaty, 1994).

The Formula of ASR

This study adopts the evaluation concept of the AQR formula, which has become widely recognized in aviation (Goodman, 1992, April 29; Spencer, 1999; Lawton, 2002), to calculate the ultimate ASR score leading to the final airline safety report.

The formula of the ASR has 17 selected safety factors and is stated as the following:

$$ASR = \frac{V1[W1F1+\ldots+W4F4]+V2[W5F5+\ldots+W8F8]+V3[W9F9+\ldots+W13F13]+V4[W14F14+\ldots+W17F17}{V1+V2+V3+V4}$$

$$= \frac{V1(WF)+V2(\Sigma WF)+V3(\Sigma WF)+V4(\Sigma WF)}{\Sigma Vi}$$

$$= \frac{\Sigma[V\Sigma(WF)}{\Sigma Vi} = \Sigma[V\Sigma(WF)]$$

Where V = the weighted value of category determined by experts via AHP output; W = the average weighted value of each variable determined by experts via; AHP output; F = the factor credits obtained from raw data; Σ = mathematic sum; ΣVi = 1, where i = 1 … 17

Purpose of Study

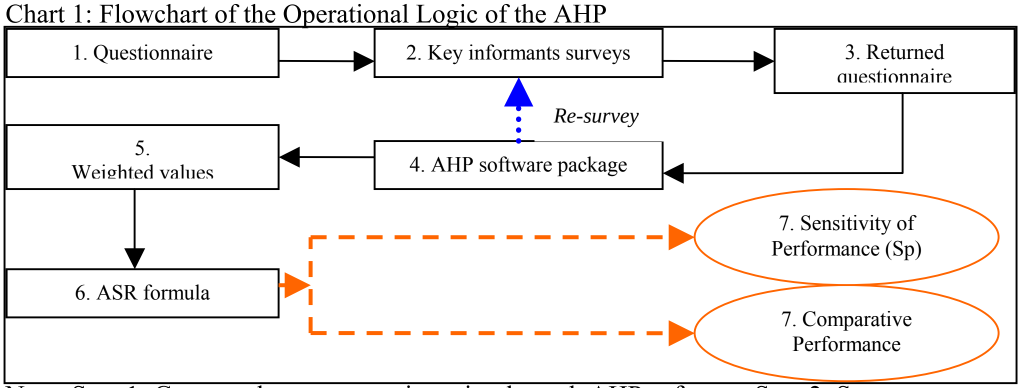
In addition to reporting safety performance across ten major airlines, the purpose of this study was to discuss the importance of selected factors in terms of its performance sensitivity (Sp) affecting airline safety. The performance sensitivity (Sp) in this study was to measure the responsiveness of the seventeen safety factors to the overall safety performance. This indication is vital for airline managers who seek to maximize their safety performance with the the minimum amount of cost involved in the near future.

Our definition of sensitivity The general formula for perofrmance sensitivity Sp (the "ASR-sensitivity of fx" where the symbol of fx represents selected safety factors) is: $S_{fx,}ASR$ = % change in fx / % change in ASR, or, more practically, $S_{fx,asr}$ = (dfx/dASR)(ASR/fx).

Explanatory Illustration of Research Processing

The following chart illustrates the operational logic of the AHP's application in this research (see Chart 1). The procedures of implementation are also attached. The core of Delphi technique is the approaching of a commentary consistency; therefore, a "resurvey" activity was initiated in this study.

Chart 1: Flowchart of the Operational Logic of the AHP



Note: Step 1: Generated survey questionnaire through AHP software. Step 2: Survey sent to aviation experts. Step 3: Retrieved raw data from replied questionnaires. Step 4: Input initial survey feedbacks to AHP for comparison. Step 5: Obtained individual weightings after comparison. Step 6: Applied weighted value to ASR formula. Step 7: Calculated safety performance and Sp. In Delphi method, the purpose of "Re-survey" phase is to re-concretize participants' opinions.

Findings

To accomplish determined goals, the authors revisited and recalculated dataset of 2001 that were essential to ASR score. This section displayed individual weight of safety category, the report of safety performance, ratio change of ASR, chronic trend of ASR, and Sp of each safety factor.

Individual Safety Category and Factor (Weights and Credits)

In the research, a total of 83 AHP questionnaires have been returned (a response rate of 75.75 percent). Seventeen (17) questionnaires were excluded due to technical deficit (judged by AHP software with low validity, index < .2), leaving a total of 65 (59 percent) valid questionnaires. The average weighted value of each safety category and factors provided in Table 1 illustrates the weighted importance judged by surveyed aviation experts.

Table 1: Average AHP Weighted Points

1. Safety Category			
FAA Enforcement Action	Accident related	Management Quality	Financial Health
0.201727273	0.309515152	0.304969697	0.179342424
2. Safety Factors			
Violation (Maintenance)	Fatality Rate	Average Fleet Age	Profitability Ratio
0.330606061	0.311030303	0.288636	0.320424242
Violation (Flight Ops)	Accident rate	On-time rate	Cash Flow Ratio
0.3305152	0.269484848	0.230606061	0.2633636
Violation (HAZMAT)	Fatality	A/C utilization	Turnover Ratio
0.184152	0.222606	0.211121212	0.214455
Violation (Security)	Incident rate	A/C on order	Liquidity Ratio
0.14667	0.19830303	0.138455	0.202667
		Code-sharing	
		0.131030303	

Note: This table represents the average weighted value of each selected variable calculated from the input of 65 returned questionnaires based on the application of AHP software. This table shows the overall aviation concerns in terms of expert opinion over the specific duration of our research. Therefore, a follow-up survey may manifest different responses due to the ongoing internal and external influence of the entire aviation industry. Furthermore, the AHP allows researchers to retrieve valuable expertise and thus helps refining the validity of each selected safety factor.

Highlights of Airline Safety Performance – FY 1996, 1997, 1998, 1999

According to synthetic ASR result provided, Southwest Airlines gained the highest ASR score in FY 1996 (7.6926), 1997 (8.4215), 1998 (7.5681), and 1999 (7.9356) (See Table 2). TWA had a difficulty in competing with its business counterparts in FY 1996, 1997, and 1998. Table 2 also showed that Southwest Airlines maintained its highest safety performance among selected airlines across four years in the 2001 study.

Table 2: Safety Performance – FY 1996, 1997, 1998, 1999

Airlines	FY 1996	1996 Rank	FY 1997	1997 Rank	FY 1998	1998 Rank	FY 1999	1999 Rank	Overall Ranking
Alaska	5.859	6	6.383	4	6.414	4	5.403	9	6
American	4.829	8	4.553	9	5.791	8	3.659	10	10
America West	6.34	4	5.662	5	6.442	3	6.107	6	5
Continental	7.485	2	4.798	7	6.331	5	7.332	2	4
Delta	4.528	9	5.111	6	5.435	9	6.174	5	7
Northwest	7.053	3	6.870	2	6.227	6	6.453	3	3
Southwest	7.924	1	8.528	1	7.692	1	7.541	1	1
United	5.329	7	4.048	10	6.065	7	5.897	7	8
US Airways	6.305	5	6.861	3	7.432	2	6.205	4	2
TWA	3.401	10	4.718	8	5.251	10	5.56	8	9

Sensitivity (Sp) of Safety Factors

The following table shows individual factor's performance sensitivity (See Table 4). The findings indicated that fatality rate (9.63%), average fleet age (8.80%), and accident rate (8.34%) were three most critical factors affecting ASR scores followed by on-time rate (7.03%). In addition, the FAA's violation related to security (2.96%) and HAZMAT (3.71%) did not play a critical role in this report as well as liquidity (3.63%) and turnover ratios (3.85%).

Table 4: Sensitivity of selected safety factors

FAA Enforcement Action	Accident Related Factors	Management Quality Factors	Financial Health Factors
Flight Ops	Fatality Rate	Average Fleet Age	Profitability Ratio
6.67%	9.63%	8.80%	5.75%
Maintenance	Accident Rate	On-time Rate	Cash Flow Ratio
6.67%	8.34%	7.03%	4.72%
HAZMAT	Fatality	Aircraft Utilization	Turnover Ratio
3.71%	6.89%	6.44%	3.85%
Security	Incident Rate	Aircraft on Order	Liquidity Ratio
2.96%	6.14%	4.22%	3.63%
		Code-sharing	
		4.00%	

Discussion and Conclusion

The findings of this study retrieved from multivariate ASR formula focused on relative comparisons in terms of more objective and broader safety measurements. Rather than a univariate basis of safety assessment, this study proposed a more comprehensive tool to the aviation community. The average weighted value of each safety category revealed that Accident/incident and Management Quality weighed heavily on the minds of surveyed aviation experts. Yet the performance of Accident/incident and Management Quality could not conclude the overall performance. To further explain, although fatality rate, accident rate, and fleet age were three most critical factors affecting ASR scores, there are other relevant factors embedded. However, many airlines are currently facing financial difficulty across different layers of their operation. Based on the findings of this study, airline must compress accident or incident rates or should update their fleet in order to promote safety performance. The challenges facing the industry are: 1) a continuous implementation of accident prevention programs to ensure the determined zero-accident goal; and 2) a consistent retirement of their aged fleet. However this task would face a similar problem as usual—financial constraint. Without spending additional costs, how to maintain a zero-accident status quo needs a long term plan. Closely enhancing employees' safety behavior and mindset is critical based on current ongoing training activities. In addition, forming a zero-accident working environment is not only airlines' responsibility, but also government's legitimate priority. This is particularly true after the tragedy of September 11.

The concepts of this paper were originated from the implemental logic of the national AQR project, the AHP innovation, and relative comparison across airlines from which the identification of performance gaps between airlines can be located for potential areas of improvement. By locating such performance deficits through detailed comparison of data sets, managerial personnel can initiate proper efforts to close up the gaps in the areas such as management, profitability, violation, security, finance, and so forth. For research transformability, this safety evaluation model can also be applied to similar projects on a quarterly, monthly, or even weekly basis. This study also proposed a capability that helps airline managers or government authorities to (a) target factors that erode aviation safety, (b) predict at-risk airlines, and (c) prepare malleable solutions ahead of schedule.

Follow-up Study

The weights of individual safety factors vary from year to year because expert panelists would likely to define a different level of importance for individual safety factor based on the virtual public concerns or external change. The authors strongly suggest a continuous measurement of safety performance. Moreover, in this study, although the factors of security and HAZMAT did not show a significant importance before September 11, it is by no means that current air transport industry should disregard its criticality.

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